Urinary tract ultrasonography in normal rams and in rams with obstructive urolithiasis

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Abstract

We determined the position, dimensions, and structure of the kidneys, ureters, bladder, and urethra in 20 healthy, adult rams by use of ultrasonography. The findings were compared with those of seven rams with obstructive urolithiasis, thus establishing criteria for the diagnosis of urolithiasis via ultrasonography. A 5.0 MHz convex transducer was placed over the right paralumbar fossa to examine the kidneys, and a 5.0 MHz linear rectal transducer was used to examine the bladder and urethra transrectally. All examinations were performed on standing rams. The left kidney had a length of 8.4 ± 0.3 cm (mean ± SD), a width of 4.7 ± 0.3 cm, and a depth of 4.4 ± 0.3 cm. The diameter of the renal sinus of the left kidney was 1.5 ± 0.2 cm. The circumference of the medullary pyramids measured 2.8 ± 0.3 cm. Similar ultrasonographic measurements were obtained for the right kidney. The mean diameter of the bladder of 12 rams was 7.5 ± 2.8 cm. The diameter of the bladder could not be determined in the remaining eight rams because it was greater than 10 cm and therefore beyond the penetration depth of the scanner. The only part of the urethra which could be visualized ultrasonographically was the internal urethral orifice. It had a diameter of 0.2 ± 0.1 cm.

Ultrasonographic examination of seven rams with obstructive urolithiasis revealed a markedly dilated urethra and urinary bladder. Due to severe cystitis, the contents of the urinary bladder appeared as multiple, tiny, uniformly distributed echoes. The renal pelvis and medullary pyramids of both kidneys were dilated in four rams. In two rams, uroperitoneum and accumulation of urine in the abdomen were diagnosed via ultrasonography. In one ram this was due to a ruptured ureter and in one to a ruptured bladder. The results of this study indicate that ultrasonography is a useful aid in the diagnosis of obstructive urolithiasis.

Résumé

Ultrasonographie du tractus urinaire normal et lors d'une urolithiase obstructive chez le bélier

Les auteurs ont déterminé par ultrasonographie, la position, les dimensions et la structure des reins, des uretères, de la vessie et de l'urètre chez 20 béliers, adultes, en santé. Ces données ont été comparées à celles obtenues chez 7 béliers présentent une urolithiase obstructive afin d'établir des critères de diagnostic d'urolithiase par ultrasonographie. Une sonde convexe de 5,0 MHz a été utilisée pour examiner les reins dans la région de la fosse paralombaire, alors qu'une sonde rectale linéaire a été employée lors de l'examen transrectal de la vessie et de l'urètre. Tous les examens ont été effectués chez les animaux en position debout. Le rein gauche mesurait 8,4 ± 0,3 cm de longueur (moyenne ± DS), par 4,7 ± 0,3 cm de largeur, par 4,4 ± 0,3 cm d'épaisseur. Le bassinet rénal avait un diamètre de 1,5 ± 0,2 cm. La circonférence des pyramides rénales était de 2,8 ± 0,3 cm. Le rein droit présentait des dimensions semblables à celles du rein gauche. Le diamètre moyen de la vessie de 12 béliers était de 7,5 ± 2,8 cm. Dans 8 cas, le diamètre de la vessie n'a pu être déterminé chez 8 béliers parce qu'il était supérieur à 10 cm, ce qui est au-delà des limites de balayage de la sonde. Une seule portion de l'urètre pouvait être visualisée par ultrasonographie, soit l'orifice urétrale interne, laquelle avait un diamètre de 0,2 ± 0,1 cm.

Les examens par ultrasonographie de 7 béliers ayant une obstruction urinaire due à une urolithiase ont démontré une distension marquée de la vessie et de l'urètre. Le contenu de la vessie apparaissait comme des échos multiples, petits, uniformément distribués en raison d'une cystite sévère. Le bassinet et les pyramides rénales des deux reins étaient dilatés chez 4 béliers. Un uropéritoine et une accumulation d'urine dans l'abdomen ont été décelés par ultrasonographie chez deux animaux; conséquences d'une rupture de la vessie, chez l'un et, d'une rupture de l'urètre, chez l'autre. Les résultats de cette étude indiquent que l'ultrasonographie est un moyen de diagnostic utile lors d'urolithiase obstructive.

(Traduit par Dr Thérèse Lanthier)

Can Vet J 1992; 33: 654–659

Introduction

Ultrasonographic examination and anatomy of the kidneys have been described for horses (1–3), cattle (4, and authors' unpublished observations), dogs (5–7), cats (8–10), and ewes (11). Ultrasonography has been used to diagnose renal calculi and cysts, renal neoplasia, hydronephrosis, cystitis, bladder diverticula, and obstruction of the lower urinary tract (1,12–16). The most common urinary tract disease in rams is obstructive urolithiasis. Usefulness of ultrasonography for diagnosis of urolithiasis in sheep and goats has been noted in the literature (17), but in depth studies have not been performed. Ultrasonography is not a routinely used diagnostic procedure in rams with urinary tract disease. One of the reasons may be the lack of normal reference values available for quantitative analysis of the kidneys, ureters, and urethra of adult rams.

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This report represents a portion of a thesis submitted by U. Schefer to the Veterinary Faculty of the University of Zurich, Switzerland as fulfillment of the requirements for the Dr. med. vet. degree.

The objective of our study was to determine the normal sonographic appearance of kidneys, ureters, bladder, and urethra in the adult ram. Various dimensions were measured from sonograms of 20 rams to establish reference values. We compared the findings with those obtained in seven rams with obstructive urolithiasis, and established criteria for the diagnosis of urolithiasis via ultrasonography.

Materials and methods

Twenty healthy rams and seven rams with obstructive urolithiasis were used. All but two were White Alpine sheep. The healthy rams were 1–12 years old (mean, 6.1 years), and weighed between 41–89 kg (mean, 65.2 kg). The rams with obstructive urolithiasis were between 1.3–6.0 years old (mean, 3.0 years).

Ultrasonographic examination

All examinations were performed while the rams were standing. The kidneys and ureters were examined from the paralumbar fossa by use of a 5.0 MHz convex real-time scanner. The bladder and urethra were examined transrectally by use of a 5.0 MHz rectal linear real-time scanner (LSC 7000, Picker International GmbH, Leu AG, St. Karlistrasse 21, CH-6004 Lucerne, Switzerland). The area over the paralumbar fossa on the right side was clipped, transmission gel was applied, and the kidneys and ureters were examined. Numerous ultrasonograms of the kidneys in both transverse and longitudinal section were viewed until the entire structure of the kidney had been studied. The echogenicities of the renal cortex, medullary pyramids, and renal sinus were assessed and compared. To visualize the right kidney longitudinally, the transducer was always placed behind the last rib high on the paralumbar fossa (Figure 1). The transducer was held slightly obliquely because the longitudinal axis of the right kidney did not lie horizontally in most cases. To visualize the left kidney longitudinally, the transducer was placed over the middle of the paralumbar fossa, parallel to the lumbar vertebrae. Transverse ultrasonographic visualization of both kidneys was performed by placing the transducer at right angles to the longitudinal axis of each kidney.

Ultrasonographic measurements included the length of the kidney (the distance between the cranial and caudal renal poles, measured in the longitudinal plane); the depth of the kidney (the distance between the ventral and the dorsal surfaces, measured in the transverse plane at the level of the renal hilus); the width of the kidney (the distance between the lateral and the medial margin of the kidney, measured in the transverse plane at the level of the renal hilus); the diameter of the renal sinus (measured from dorsal to ventral in the transverse plane at the level of the renal hilus); and the circumference of three medullary pyramids.

For the transrectal ultrasonographic examination, a 5.0 MHz linear rectal transducer was introduced into the rectum with the beam directed ventrally. The diameters of the bladder and internal urethral orifice were determined, and the bladder wall, bladder contents, and internal urethral orifice were visualized. The pelvic parts of the urethra were also examined trans-

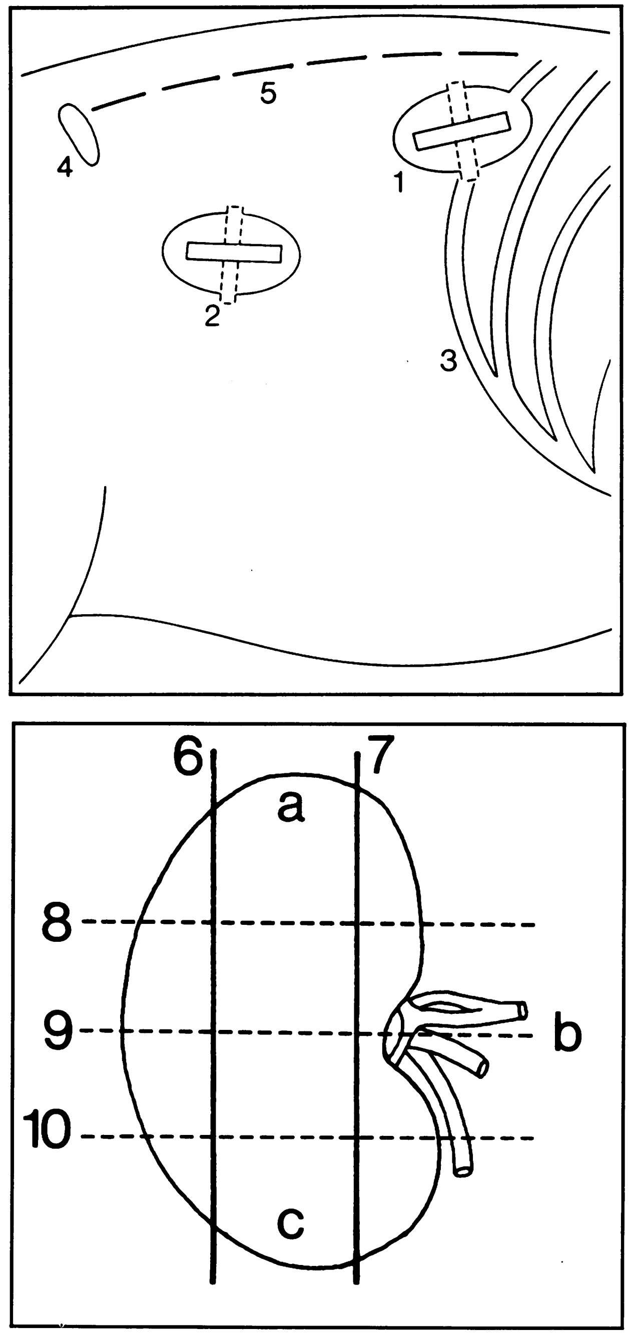

Figure 1. A and B. Position of the transducer (A) for the ultrasonographic examination of the kidneys in longitudinal (transducer outlined) and transverse (transducer broken line) section and schematic representation (B) of longitudinal and transverse sections through the kidneys. 1 = position of the transducer for the ultrasonographic examination of the right kidney; 2 = position of the transducer for the ultrasonographic examination of the left kidney; 3 = last rib; 4 = point of the hip; 5 = transverse processes of the lumbar vertebrae; 6 = lateral longitudinal section through the kidney; 7 = medial longitudinal section through the kidney; 8 = transverse section through the kidney cranial to the renal hilus; 9 = transverse section through the kidney in the region of the renal hilus; 10 = transverse section through the kidney caudal to the renal hilus; a = cranial pole of the kidney; b = renal hilus; c = caudal pole of the kidney.

rectally. The transducer was placed so that the area of the internal urethral orifice was visible on the cranial side of the ultrasonogram. An attempt to follow the urethra caudally was then made. A 5.0 MHz convex

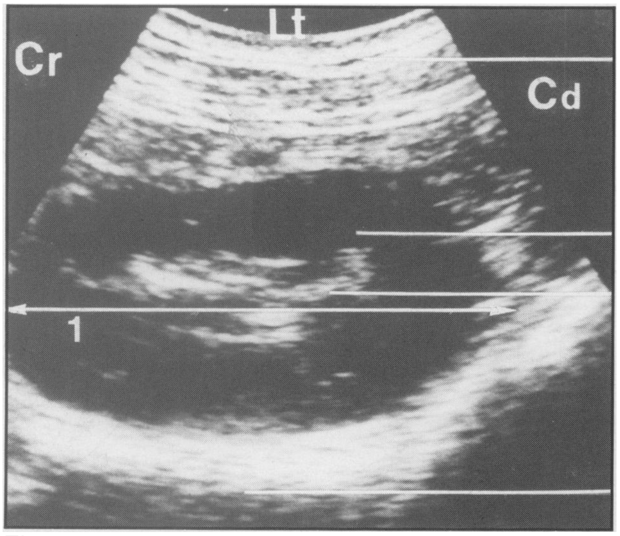

Figure 2. Ultrasonogram of a medial longitudinal section through the left kidney. 1 = length of the kidney; top line = abdominal wall; second line = renal parenchyma; third line = renal sinus; bottom line = ruminal wall; Cd = caudal; Cr = cranial; Lt = lateral.

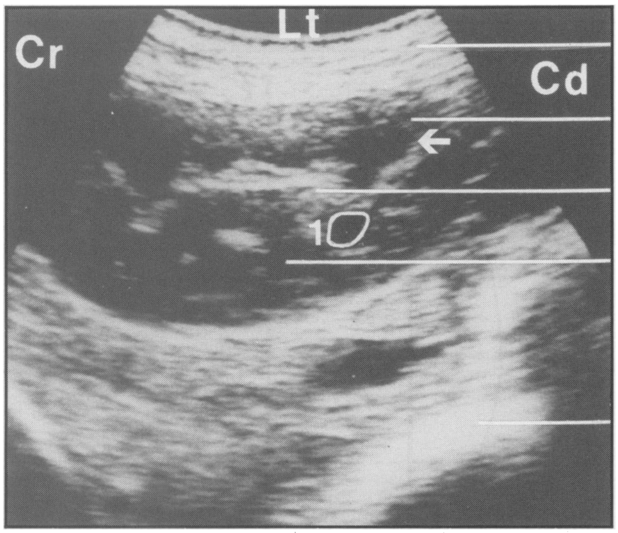

Figure 3. Ultrasonogram of a lateral longitudinal section through the left kidney. Top line = abdominal wall; second line = renal cortex; third line = renal sinus; fourth line = medullary pyramid; bottom line = ruminal wall; arrow = renal medulla; Cd = caudal; Cr = Cranial; Lt = lateral; 1 = circumference of a medullary pyramid.

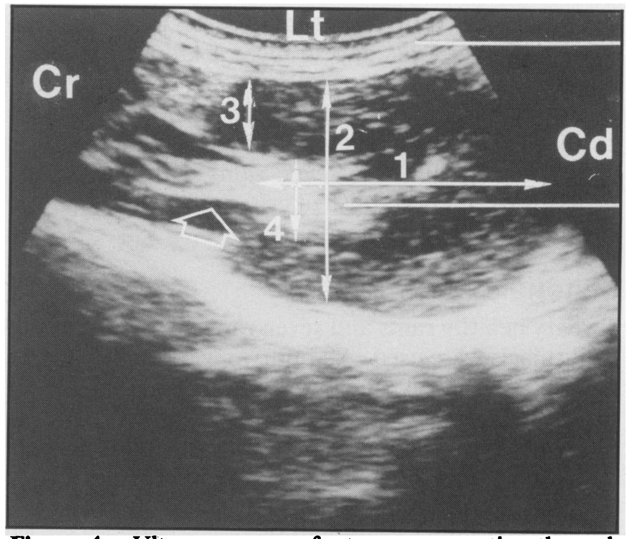

Figure 4. Ultrasonogram of a transverse section through the right kidney in the region of the renal hilus (arrow). Top line = abdominal wall; second line = renal sinus; Cr = cranial; Cd = caudal; Lt = lateral; 1 = width of the kidney; 2 = depth of the kidney; 3 = diameter of renal parenchyma; 4 = diameter of renal sinus.

transducer was used to examine the penile part of the urethra in standing rams. The transducer was placed between the thighs to ultrasonographically visualize the urethra in the area of the sigmoid flexure. The transducer was moved 90° in an attempt to obtain an image of the urethra longitudinally and transversely. Efforts were made to image the urethra along its length both transversely and longitudinally.

The measurements were made using electronic calipers. The normal range of a parameter was defined as the mean ± two standard deviations (SD).

Examination of rams with obstructive urolithiasis
All rams with obstructive urolithiasis underwent a thorough clinical examination including inspection and palpation of the penis. Hematocrit and serum urea and creatinine concentrations were determined, and ultrasonographic examination of the urinary bladder and urethra was performed. In four cases, the kidneys were also examined ultrasonographically. All rams with obstructive urolithiasis were euthanized because of the severity of disease and poor prognosis. The postmortem examination confirmed the clinical diagnosis of obstructive urolithiasis in all seven rams.

Statistical analysis
The statistical calculations were performed by means of a calculation program (SPSS/PC, V2.0, SPSS Inc., Chicago, Illinois, USA) according to the method of Norusis (18).

Results

Ultrasonographic findings in 20 healthy rams
All kidneys could be visualized. The surface of both kidneys was smooth. The ultrasonographic images of the kidneys of all healthy rams (Figure 2) appeared the same as those recently described for healthy ewes (11). The centrally located, hyperechogenic renal sinus was easily distinguished from the surrounding hypoechogenic renal cortex and medulla. Ultrasonographically, the renal medulla consisted of anechoic, circular, medullary pyramids (Figure 3). The renal cortex appeared uniformly gray and was less echogenic than the renal sinus. The renal hilus could always be visualized in the transverse image of the kidney (Figure 4). Occasionally, the renal vein and artery and the ureter could be visualized in the region of the renal hilus; however, they could not be differentiated from one another.

Means, standard deviations, and normal ranges of the measurements were calculated (Table 1). There was very little difference between the variables measured for the right kidney and those for the left.

The course of the ureters could not be visualized ultrasonographically in any of the rams by means of the transrectal or flank approaches. In a few sheep, the opening of the ureter into the bladder could be

Table 1. Results of ultrasonographic examination of the urinary tract of 20 adult White Alpine rams[a]

Variable	Mean	SD	Normal range[b]
Left kidney			
Length	8.4	0.3	7.8 to 9.1
Width	4.7	0.3	4.1 to 5.3
Depth	4.4	0.3	3.8 to 5.1
Diameter of renal sinus	1.5	0.2	1.2 to 1.9
Circumference of medullary pyramids	2.8	0.3	2.1 to 3.4
Right kidney			
Length	8.2	0.3	7.5 to 8.9
Width	4.8	0.3	4.2 to 5.4
Depth	4.5	0.3	4.0 to 5.1
Diameter of renal sinus	1.5	0.2	1.2 to 1.8
Circumference of medullary pyramids	2.8	0.3	2.2 to 3.3
Urinary bladder			
Diameter[c]	7.5	2.8	1.8 to 13.2
Thickness of the wall	0.2	0.1	0.1 to 0.5
Urethra			
Diameter	0.2	0.1	0.1 to 0.3

[a]All variables are given in centimeters
[b]Normal range = mean ± 2 SD
[c]Determined in only 12 rams, since the diameter exceeded the penetration capacity of the scanner (10 cm) in the remaining eight animals

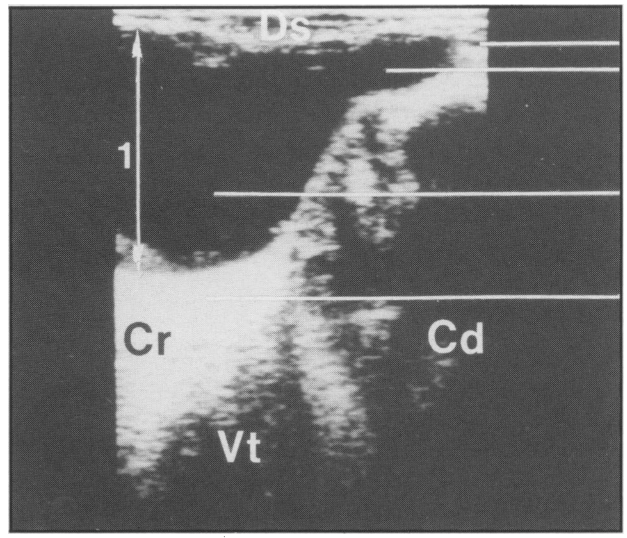

Figure 5. Ultrasonogram of a longitudinal section through the urinary bladder obtained transrectally with a 5.0-MHz linear rectal transducer. Top line = partially visible urethral lumen; second line = neck of the urinary bladder; third line = urinary bladder; bottom line = posterior enhancement; Ds = dorsal; Vt = ventral; Cd = caudal; 1 = diameter of the urinary bladder.

observed when there was a flow of urine into the bladder.

The bladder could be ultrasonographically visualized in all rams (Figure 5). The contents of the bladder were hypoechogenic and the bladder wall was uniform in thickness and smoothly demarcated inside and out. The mean diameter of the bladder of 12 rams was 7.5 ± 2.8 cm. The smallest diameter measured was 2.1 cm. In eight rams, the diameter of the bladder could not be measured because it was larger than 10 cm and therefore beyond the penetration depth of the scanner.

The urethra in the region of the internal urethral orifice could be visualized clearly in 18 rams. The course of the urethra in the pelvis and in the penis could not be imaged ultrasonographically in any of the rams. The diameter of the urethra was 0.1 to 0.3 cm (0.2 ± 0.1 cm).

Ultrasonographic findings in rams with obstructive urolithiasis

In all rams with obstructive urolithiasis, the bladder was markedly dilated and its diameter could not be measured transrectally because it was beyond the penetration capacity (10 cm) of the scanner. In two rams, the bladder was visualized from the hairless area of the inguinal region, and its diameter was 10.4 and 13.5 cm. In contrast to healthy sheep, the bladder content of rams with obstructive urolithasis was not hypoechogenic. Instead, it appeared as multiple, tiny, uniformly distributed echoes which were observed mainly in the ventral part of the bladder (Figure 6). In all rams, the proximal part of the urethra was dilated (Figure 6). Its greatest diameter was 2.3 cm. In one ram, the bladder contained a urinary calculus which appeared similar in radiographs and ultrasonograms. Ultrasonographically, it appeared hyperechoic with an acoustic shadow. In four rams, the pelves and medullary pyramids of the kidneys were dilated because of urinary stasis. In ram 4, the right kidney was markedly enlarged (length of the right kidney 13.2 cm, length of the left kidney 8.4 cm). The ureter was ruptured in the region of the left renal hilus. This resulted in fluid accumulation retroperitoneally and in the abdominal cavity, both of which were visible sonographically. In ram 7 the bladder was ruptured. The resulting fluid accumulation in the abdominal cavity was also visible sonographically (Figure 7).

At postmortem, rams 1 and 3 had urinary calculi; each ram had one calculus in the urinary bladder and one calculus in the urethra (ischiatic arch). Ram 2 had urinary sediment in the bladder. Ram 4 had a ruptured left ureter at the renal hilus due to obstruction by urinary sediment; in addition, there was urine in the abdominal cavity and retroperitoneally and a urinary calculus in the urethral process. Ram 5 had one urinary calculus in the urethral process and one urinary calculus in the urethra (sigmoid flexure). Ram 6 had urinary sediment in the urethral process. Ram 7 had a ruptured bladder and urine in the abdominal cavity. Additionally, this ram had urinary calculi in the bladder and in the urethra. All rams had severe cystitis and urine containing blood and sometimes floccules.

Discussion

The purpose of our study was to describe the ultrasonographic appearance of the male ovine urinary tract. In addition, several anatomic variables were assessed quantitatively. The results indicate that the kidneys can be visualized ultrasonographically from the body surface and that the bladder and the proximal portion of the urethra (a few centimeters) can be

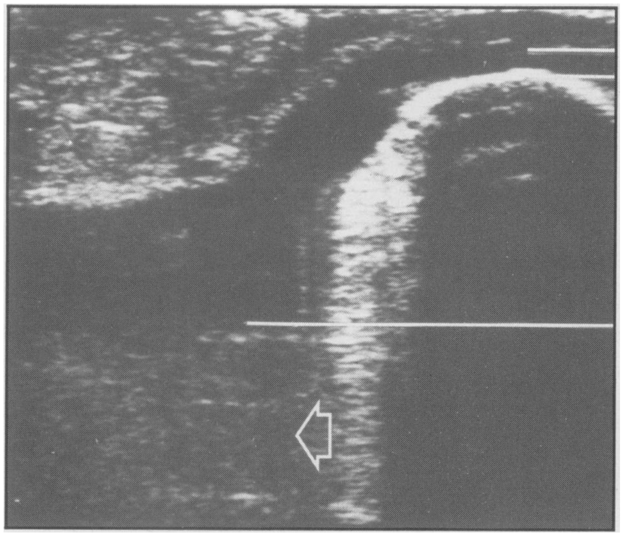

Figure 6. Ultrasonogram obtained transrectally with a 5.0 MHz linear rectal transducer of a longitudinal section through the dilated urinary bladder of a ram with obstructive urolithiasis. Urethra and urinary bladder are dilated. The urinary bladder cannot be fully imaged in its ventral region because of its large diameter. Notice the numerous weak echoes in the ventral part of the urinary bladder (arrow). Top line = urethra; second line = pelvic floor; bottom line = urinary bladder.

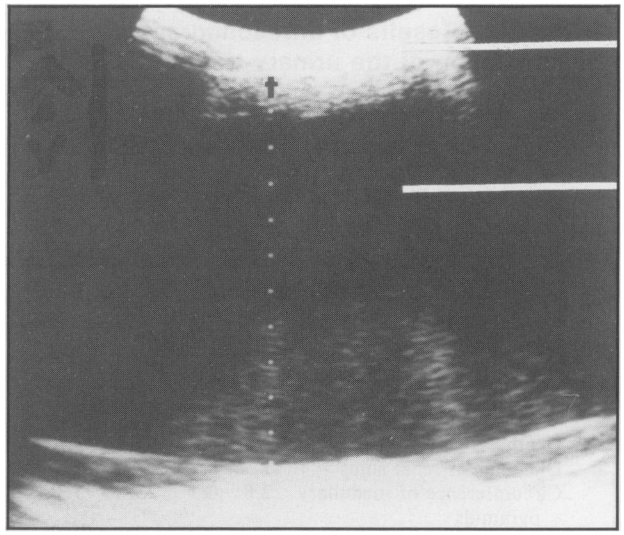

Figure 7. Ultrasonogram obtained from the linea alba of a ram with urine accumulation in the abdomen because of rupture of the urinary bladder. Top line = abdominal wall, second line = urine accumulation in the abdomen, + = cursor marks; dots = distance between cursor marks (10.8 cm).

imaged transrectally. The ureters, however, could not be observed via ultrasonography. The diameter of the bladder could not always be measured transrectally; in eight rams, it was greater than 10 cm and therefore beyond the penetration capacity of the 5.0 MHz rectal transducer. In such cases, a 2.5 MHz convex transducer can be placed over the hairless area of the inguinal region with the beam aimed dorsomedially to visualize the ventral parts of the bladder. This technique works well when the bladder is full; however, the bladder cannot always be visualized when it is only partially full. The examinations in this study were performed on White Alpine sheep. Although we have had little experience with other breeds of sheep, it is reasonable to assume that the findings of ultrasonographic examination of the urinary tract of other sheep breeds would be similar.

It is evident from the results of this study that ultrasonography is a useful aid in confirming a clinical diagnosis of obstructive urolithiasis, the most common urinary tract disease in rams. The pathogenesis, clinical signs, therapy, and prophylaxis of this disease have been described in detail (17,19–21). Clinical signs include anuria or the passage of only a few drops of urine, kicking at the abdomen, stamping the feet, tail swishing, bruxism, repeated efforts to urinate, and a rapid deterioration of general condition. If the urethra ruptures, urine accumulates in the subcutaneous tissue. Rupture of the bladder results in accumulation of urine in the abdominal cavity and abdominal distension.

A diagnosis of ruptured bladder or urethra usually cannot be made based on clinical signs alone; ultrasonography is a very useful aid in confirming a tentative diagnosis. It should be emphasized that a thorough clinical examination is the most important aspect of diagnosing obstructive urolithiasis in rams. The examination should include observation of the ventral abdomen for edema, examination of the preputial orifice for saline crystals, palpation of the penis in the area of the sigmoid flexure, and examination of the urethral process of the exteriorized penis. In addition, serum urea and creatinine concentrations should be determined, and abdominocentesis performed. The latter quickly confirms a tentative diagnosis of rupture of the bladder. When these procedures have been completed, ultrasonographic examination of the urethra, bladder, and kidneys should be performed to confirm diagnosis. In rams, the diagnosis of obstructive urolithiasis cannot be made based on the ultrasonographic visualization of a very full bladder because this also may be seen in healthy rams. A more important criterion is the visualization of a dilated urethra because this does not occur in healthy sheep. The ultrasonographic appearance of the contents of the bladder can also aid in a diagnosis. In the study reported herein, rams with obstructive urolithiasis were in advanced stages of the disease. They had severe cystitis and marked changes in the urine which appeared as multiple, uniformly distributed, tiny echoes on ultrasonograms. The bladder should be examined via ultrasonography for urinary calculi. These appear as intense echoes, which when sufficiently large, result in shadowing (22), and which change their position in the bladder when the patient is moved. In this study, only one urinary calculus could be visualized ultrasonographically. This was probably because most urinary calculi in sheep are only 1–3 mm in size (23). Urinary calculi less than 3 mm can be identified under standardized conditions *in vitro*; however, *in vivo*, urinary calculi must be at least 3–4 mm to be recognized (24). In rams with possible obstructive urolithiasis, the ureters, which are not ultrasonographically visible in healthy sheep, should be examined for dilation and for possible urinary calculi.

Before performing corrective surgery, it is important to ultrasonographically visualize both kidneys. The prognosis would be very guarded if there were renal calculi or a ruptured kidney (17). Similar to findings in human beings (25), four rams in this study had dilated renal pelves and medullary pyramids attributable to urinary stasis. In ram 4, rupture of the ureter, uroperitoneum, and accumulation of urine in the abdominal cavity, and in ram 7, rupture of the bladder and accumulation of urine in the abdominal cavity, were diagnosed via ultrasonography. This supports the suggestion that ultrasonography may be a useful aid for diagnosing fluid accumulation in the abdomen of sheep (17).

In conclusion, in rams with a tentative diagnosis of obstructive urolithiasis, all parts of the urinary tract should be thoroughly examined for urinary calculi. The clinician should examine the kidneys for enlargement and the renal pelves, medullary pyramids, urethra, and ureters for dilatation. The size of the bladder should be noted and its contents examined. A ruptured bladder does not always empty completely. Thus, the ventral abdomen should be examined via ultrasonography for the accumulation of urine in the abdominal cavity. Together with the clinical examination, urinalysis, determination of serum urea and creatinine concentrations, and abdominocentesis, ultrasonography provides a useful aid in the diagnosis of ovine urolithiasis.

Although ultrasonographic examination of the urinary tract is easily and quickly performed, it is only occasionally carried out in sheep with urolithiasis because of the low financial value of these animals. It is understandable that an exact diagnosis is not worthwhile in sheep that are kept only to graze non-tillable land or for commercial reasons, especially when only a single case is involved. However, there has been an increase in the number of sheep kept as pets or for hobby purposes. Owners of these sheep are more interested in having sick sheep professionally examined and treated. The diseased rams in this study consisted exclusively of breeding rams, which are valued for their blood lines. CVJ

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